New evidence and revised interpretations of early agriculture in Highland New Guinea

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Tim Denham, Simon Haberle & Carol Lentfer

This review of the evidence for early agriculture in New Guinea supported by new data from Kuk Swamp demonstrates that cultivation had begun there by at least 6950-6440 cal BP and probably much earlier. Contrary to previous ideas, the first farming in New Guinea was not owed to South-East Asia, but emerged independently in the Highlands. Indeed plants such as the banana were probably first domesticated in New Guinea and later diffused into the Asian continent.

Keywords: Mid-Holocene, New Guinea Highlands, agriculture, Musa bananas

Introduction

Several areas in the Highlands of New Guinea, in particular the Upper Wahgi Valley, are significant for interpreting the emergence of agriculture during the early to mid-Holocene. Of these sites, Kuk Swamp (hereafter referred to as “Kuk”) is the most important because it has been investigated in greatest detail, provides the longest chronology and is the “type-site” for the investigation of prehistoric plant exploitation in the interior of New Guinea (Denham 2003a; Denham et al. 2003; Golson 1977a, 1982, 1985, 1990, 1991a, 1991b; Golson & Hughes 1980; Hope & Golson 1995). The international significance of Kuk derives from the presence of successive phases of drainage for agriculture dating from 6950-6440 cal BP or earlier (Golson 1977a, 1991a, 1991b; Golson & Hughes 1980; cf. Denham 2004; Denham et al. 2003; Table 1, see http://antiquity.ac.uk/ProjGall/denham). The evidence at Kuk has provided a basis for the interpretation of early and independent agricultural origins in the Highlands of New Guinea.

In this paper, new multi-disciplinary findings on early and mid-Holocene plant exploitation at Kuk, including archaeological, archaeobotanical and palaeoecological research, are presented and interpreted with respect to the prehistory of the Upper Wahgi Valley. These results endorse previous interpretations that New Guinea was a centre of independent agricultural origins, but question previous ideas that agriculture was necessarily developed in the lowlands and brought into the Highlands with climatic amelioration and stabilisation at the beginning of the Holocene (Hope & Golson 1995: 818-819, 827-8). According to our alternative argument,
New evidence and revised interpretations of early agriculture in Highland New Guinea

agricultural practices arose in the Highlands of New Guinea during the early to mid-Holocene through the transformation of pre-existing plant exploitation strategies (following Denham & Barton in press; Haberle 1993: 299-305); the nature and timing of the earliest innovations require clarification through further research.

The early and mid-Holocene remains, corresponding to Phases 1 and 2 at Kuk, are directly relevant to understanding the origins of agriculture in New Guinea. The early and mid-Holocene remains pre-date any known Southeast Asian influence on New Guinea after its initial colonisation by at least c. 40 000 cal BP (Groube et al. 1986). Mid-Holocene Southeast Asian influences are usually associated with the expansion of Austronesian language-speakers to Melanesia at 3500-3300 cal BP (see Bellwood 1997: 210-54), or at c. 3200-3300 cal BP (Spriggs 2001: 240). The influence of Austronesian diffusion on mainland New Guinea, marked by the Lapita cultural complex in island Melanesia (Green 1991), is unclear because there is a near absence of Lapita pottery and other well-dated traits on the island of New Guinea (see Terrell & Welsch 1997 for the exceptions). On linguistic grounds, Austronesian influence on New Guinea is considered to post-date the onset of Lapita culture by at least 1000 years (Bellwood 1996: 487).

Site location

The wetland archaeological site at Kuk Swamp is located approximately 12 kilometres (km) north-east of the town of Mount Hagen in the Upper Wahgi Valley, Western Highlands Province, Papua New Guinea (Figure 1). Kuk is located in the Highlands, i.e., land above 1200 metres above mean sea level (m), at an altitude of c.1560 m. Kuk Swamp forms part of extensive wetlands carpeting the floor of the Upper Wahgi Valley, which is part of one of the largest inter-montane valleys in the interior of New Guinea. The archaeological site is located on the former Kuk Agricultural (originally Tea) Research Station that covered 280 hectares (ha). Approximately 100 ha of the southeast corner were subject to multi-disciplinary investigation (Golson 1977a: 610).

Like other wetlands in the Highlands of Papua New Guinea, Kuk was artificially drained in the late 1960s and early 1970s for planting. Prior to drainage some parts of the wetland were underwater and surface gradients were generally "less than 1 in 200" (Golson 1977a: 612), except for scattered low mounds of older, tephra-mantled lahar deposits over and around which the wetland had accumulated (Pain et al. 1987: 268).

The Upper Wahgi Valley has a lower montane humid climate with an average annual temperature of 19°C and annual rainfall of c. 2700 mm (Hughes et al. 1991: 229). Climate in the Upper Wahgi Valley is dominated by local orographic effects (Powell et al. 1975: 2). A slight dry season occurs in the Upper Wahgi Valley between May and June, although soil water content does not usually limit plant growth (McAlpine et al. 1983: 74, 137).

Problems with previous research

Previous claims and evidence for early and independent origins of agriculture in New Guinea have been treated cautiously (Harris 1996: 568-9; Richerson et al. 2001: 400; Smith 1998: 142-3), or been ignored (Harlan 1995). Doubts have been fostered by problems with the limited archaeological, archaeobotanical and palaeoecological evidence presented. Only limited archaeological evidence associated with Phases 1 and 2 at Kuk was previously published (Bayliss-
Smith 1996: 508; exceptions being Golson 1976, 1977a: 613-4, 1991a, 2000; Golson & Hughes 1980) and interpretations of the Phase 1 evidence changed through time (Bayliss-Smith 1996: 508-9). Consequently, the antiquity, mode of formation and function of palaeochannels and constituent features on the Phase 1 and 2 palaeosurfaces were uncertain (after Smith 1998: 142-3 and Spriggs 1996: 528). Findings contemporary with Phase 2 were reported at other sites in the interior, with some published in detail, e.g. Mugumamp (Harris & Hughes 1978), although all were interpreted in terms of the Kuk sequence (Denham 2003b).

Furthermore, the extent of landscape change coincident with the early and mid-Holocene drainage phases at Kuk and anticipated to accompany agro-ecosystems was unknown (Spriggs 1996: 528). Geomorphological investigations indicated accelerated rates of deposition on the wetland margin from the early Holocene, which were suggestive of erosion following vegetation clearance for swidden-type dryland cultivation in the catchment (Golson & Hughes
New evidence and revised interpretations of early agriculture in Highland New Guinea

1980: 296-7; Hughes et al. 1991: 233-234). Powell's pollen diagrams from three other sites in the Upper Wahgi Valley, at Draepi-Minjigina, Lake Ambra and Warrawau, indicated that forest clearance had occurred on a regional scale by the mid-Holocene (Powell 1982b: 218); the commencement and intensity of these activities were unknown because there was an absence of a terminal Pleistocene and early Holocene component in the relevant Upper Wahgi Valley pollen diagrams. Deposition rates at Kuk, as well as Haberle et al.’s (1991) evidence of cumulative forest clearance pre-dating 7800 cal BP in the Baliem Valley, suggested the Wahgi clearances could plausibly date to the early Holocene and be synchronous with Phase 1 archaeological remains at Kuk (Hope & Golson 1995: 823-5).

In addition, there was a near-absence of published archaeobotanical evidence of former crop plants, domesticated or otherwise (Bayliss-Smith 1996: 508; Spriggs 1996: 528). Macrobotanical remains of several edible plants and *Musa* banana phytoliths were documented for archaeological phases at Kuk (Powell 1982a; Wilson 1985). The associations of these botanical remains were uncertain because the plants could have dispersed independently of intentional human practices.

Each of these problems has been redressed by the recent investigations at Kuk.

**Archaeological evidence of cultivation practices**

Over 200 trenches were excavated at Kuk to delimit field systems and house sites (see Figure 2). Most excavations investigated later ditch networks (Phases 3-6) and comparatively few explicitly

![Figure 2: Plan of the south-east of Kuk Station showing the extent of excavations directed by Jack Golson in 1972-7 and by Tim Denham and Jack Golson in 1998-9.](image-url)
targeted early to mid-Holocene remains (Phases 1-2). The excavations undertaken in 1998 and 1999 were intended to clarify contentious archaeological finds from previous work and to obtain samples for multi-disciplinary analyses.

**Phase 1 at 10 220-9910 cal BP**

Archaeological evidence unique to Kuk was claimed to represent management of the wetland margin for agriculture at c.10 000 cal BP (Golson 1977a: 613-5; 1989: 679; 1991a; Golson & Hughes 1980; Hope & Golson 1995: 824). Formerly, the archaeology of Phase 1 consisted of “chronologically and perhaps functionally associated” (Golson 1981: 56) palaeochannel and palaeosurface. The palaeochannel was 2 m wide and 1 m deep and traced for at least 500 m across the wetland (Golson 1977a: 613-5; 2000: 232). A human origin for the palaeochannel was inferred from several characteristics including “directness of line between points of abrupt change in direction, one of them in a middle of a low hillock of volcanic ash” (Golson 1991a: 485) and by analogy with later palaeochannels, which were similarly interpreted to be artificial (Golson 2000: 232). More recent research has challenged this interpretation, and here the early palaeochannel is not considered to be artificial (Denham 2004: 47-53). The aggregates and abundant macrobotanical remains, as well as pollen and microcharcoal signals, within palaeochannel fills are consistent with forest disturbance using fire and erosion within the catchment (see below).

The palaeosurface, by contrast, consists of pits, runnels, stake- and post-holes associated with sparse artefacts, relatively heterogenous feature fills and an immature soil profile (Figure 3b). The artificiality of palaeosurface features has been determined from the morphology of features which have well-defined, cut edges. The inferred functions of features are consistent with planting and digging (pits), localised overland flow (runnels) and staking of plants (stake and post holes) within a cleared plot (after Powell et al. 1975: 24-6). The slightly heterogeneous feature fills and pedogenesis are consistent with limited mechanical admixture and the formation of immature A/C profiles within an alluvial setting (after Collins & Lavney 1983; Haywood 1985). Lastly the artificial character of the palaeosurface is confirmed by the presence of stone tools, which display evidence for the processing of starchy and woody plants and include a flake used to process taro (Colocasia esculenta) (Denham et al. 2003: 191).

Based on excavations to date, features are restricted to higher ground adjacent to the palaeochannel. This area was only dry enough to utilise for a short period, perhaps only once, prior to abandonment. In contrast to previous portrayals, these features need not represent specialised wetland management, but may be the spatial extension of plant exploitation practices from adjacent dryland slopes.

The plant exploitation practices represented by early Holocene features are unclear. Features could be associated with relatively adventitious plant management and use, although from a different perspective they could be consistent with practices in an inter-cropped, swidden-type plot on the wetland edge. Without additional investigations, it is not possible to determine if these features represent “agriculture”, as previously claimed, or other activities.
Figure 3 Archaeostratigraphic summary of Phases 1 and 2 at Kuk (modified with permission from Denham et al. 2003: Figure 2). Field plans were drawn by Arthur and Cherie Rohn. Photographs were taken by E.C. Harris in 1977 and reproduced courtesy of Jack Golson, Records of the Australian Museum (photo b) and Archaeology in Oceania (photo c).
Phase 2 at 6950-6440 cal BP

Mid-Holocene finds at Kuk represent the earliest, unequivocal evidence for agriculture in New Guinea (Denham et al. 2003; Golson 1977b: 48-9, 1989: 679, 1991a: 484, 489; Hope & Golson 1995: 823). Phase 2 at Kuk was formerly characterised as consisting of at least four successive palaeochannels that articulated with palaeosurfaces comprised of interconnected networks, or more dispersed features (Golson 1977a: 615-9). As with the early Holocene palaeochannel, there is insufficient evidence to determine that the mid-Holocene watercourses were human-made (Denham 2003b: 163-4). Palaeochannel characteristics, including slightly sinuous planforms, cross-sectional morphologies and long-profile gradients, are arguably consistent with unmodified watercourses.

The Phase 2 palaeosurface has well-connected (integrated) and less-organised (discrete) areas. The integrated areas have been studied in detail and consist of regular-to-semi-regular networks of cut features defining upraised areas, previously referred to as raised “island beds” (Golson 1977a: 616), against the underlying grey clay (Figure 3c). Similar mid-Holocene palaeosurfaces are preserved at Warrawau (Golson 2002) and Mugumamp (Harris & Hughes 1978) in the Upper Wahgi Valley, with proximal locales at Kana (Muke & Mandui 2003) and Ruti (Gillieson et al. 1985) providing more equivocal evidence (see Figure 1; reviewed in Denham 2003b: 169-74). The preserved “island beds” represent the truncated bases of former mounds constructed on the wetland margin for cultivation. At the time of initial formation, grey clay was probably a B-horizon, with the original topsoil only surviving as displaced remnants within feature fills. X-radiographs and thin sections depict greater heterogeneity within fills in comparison to adjacent stratigraphic units, which lends support to previous interpretations of mound construction.

Artefacts collected from Phase 2 contexts are sparse, which is anticipated at an agricultural site in Highland New Guinea where wooden tools were more probably used (Golson 1977c). Lithic artefacts were used to process Colocasia taro, probable Zingiber gingers and other unidentified plants (Denham et al. 2003: 191-2, Table S3). Additionally, one palaeosurface feature exhibits anomalously high Musaceae (banana) phytolith frequencies, including seed phytoliths of Eumusa, which are interpreted to represent deliberate planting within grassland maintained by burning (Denham et al. 2003: 191-2, Figure 3).

Previous interpretations suggested that moulded cultivation enabled the multi-cropping of plants with different edaphic requirements (Golson 1977a: 617). Water-tolerant plants, e.g. Colocasia taro, could potentially have been planted within the damper features between mounds, whereas water-intolerant plants, e.g. sugarcanes (Saccharum spp.), Musa bananas, yams (Dioscorea spp.), edible pitpit (Setaria palmifolia) and mixed vegetables could have been planted and staked on the “island beds” (Golson 1977a: 616, 1981: 57-8; Powell et al. 1975: 42). Archaeological and archaeobotanical evidence is consistent with this agricultural interpretation.

**Palaeoecology and landscape transformation**

Palaeoecological studies in New Guinea rely on a series of criteria to distinguish human impacts from natural processes in a record of vegetation history. These primarily include the identification of processes that did not previously occur in the palaeoecological record such as indications of forest decline and burning, and increases in secondary forest and herbs.
New evidence and revised interpretations of early agriculture in Highland New Guinea

(Haberle 1994). Pollen records from Lake Ambra, Draepli-Minjigina and Warrawau (Manton’s) Plantation in the Upper Wahgi Valley document disturbance to the primary forest that pre-dated 6200-5700 cal BP (Powell 1970a: 199, 1980: 19, 1981: 306, 1982b: 218; Figure 4). Lake Ambra and Draepli-Minjigina signalled a change from undisturbed primary forest in the late Pleistocene to a disturbed environment with higher percentages of woody non-forest species by the mid-Holocene (Zone III; Powell 1970b: 165-86, 1981: 306). Similarly, the M1 core from Warrawau depicted the establishment of secondary forest from the beginning of the pollen diagram at 5500 cal BP (Powell 1970b: 155-9; Powell et al. 1975: 43-4, 46-8). Secondary forest was represented by light demanding species including Trema sp., Acalypha sp., Macaranga sp. and Dodonaea sp.

These Wahgi Valley sites record further declines in forest cover at different times over the following 4000 years (Powell 1982b: 218), suggesting a mosaic and time-transgressive pattern of forest clearance activity throughout the mid and late Holocene. Other studies across the Highlands also

Figure 4 Diagram of stratigraphy, inferred chronology and summary arboreal pollen with Poaceae (pollen sum for all taxa based on total forest and woody non-forest taxa) from three swamp sites in the Upper Wahgi Valley (redrawn and amended with permission from Powell 1982b: 219, Powell 1982b: 221 and Powell 1970b: Figure 8.7, respectively). Solid lines mark comparable pollen assemblages at the three sites based on pollen assemblages and correspond approximately to inferred ages given in the original texts: Zone I (before 21 000 BP), Zone II (c. 21 000-6000 cal BP) and Zone III (c. 6000 cal BP-present). Calibration of $^{14}C$ ages after 19 200 BP are based on Stuiver and Reimer (1993) and before 19 200 BP are derived from a linear conversion following Bard et al. (1990).
show evidence of mid-Holocene forest clearance (Haberle 1994: Figure 8.2). Of most significance, human clearance of primary forest at Kelela Swamp in the Baliem Valley occurred prior to c. 7800 cal BP, with continued disturbance and the establishment of extensive grasslands by 3000 cal BP (Haberle et al. 1991).

The early Holocene gap in the pollen records from the Upper Wahgi Valley has been filled by recent research at Kuk. Samples collected from a core extending from the Late Pleistocene to late Holocene, as well as those collected from the fills of palaeosurface features and palaeochannels, enable detailed reconstructions of palaeoenvironments during the early and mid-Holocene (Figure 5). A composite diagram incorporating a previously unpublished pollen diagram from Kuk (Powell 1984) illustrates the swamp vegetation history from before the Last Glacial Maximum (LGM) through to the present (Figure 6).

Cold-adapted vegetation in the form of grass and sedge dominated wetlands persisted through to the early Holocene at least partially under the influence of fire (zone K-1). In the early Holocene (zone K-2), the

Figure 5 Composite pollen diagram showing selected pollen and spore taxa (percent base on total pollen and spore sum excluding aquatics) plotted as sample numbers and ordered according to archaenstratigraphic associations (left of diagram). The Musaceae phytolith frequency curve is derived from the percent of total phytoliths (counted separately). Significant pollen zones (K-1 to K-4) are shown on the right side of the diagram. Calibrated age ranges based on Denham et al. 2003: Tables S1 and S2.
mixed-montane forest is replaced by a more open forest environment with *Pandanus* (probably *P. antaresensis*) and *Schefflera* as important swamp forest components. Between 10,200 cal BP and 7400 cal BP (zones K-2 and K-3), and during deposition of a distinctive grey-brown clay on the wetland margin, grasslands and fern flora increase at the expense of forest which is under the influence of periodic fire episodes. At the same time, the catchment forest composition changes from dominance of montane canopy taxa, such as *Nothofagus*, *Castanopsis* and gymnosperms to subcanopy taxa, particularly *Pandanus*. At the beginning of the mid-Holocene, at around 7000 cal BP (zone K-4), there is a rapid loss of forest associated with increased burning and an open grass-sedge swampland is established.

The new palaeoecological evidence from Kuk, in conjunction with previous diagrams at Draepi-Minjigina, Lake Ambra and Warrawau, indicates that forest clearance, widespread use of fire and the establishment and maintenance of disturbed environments were regional processes across the Upper Wahgi Valley from at least 7000-6500 cal BP. Taken in conjunction with archaeological evidence for prehistoric mounding at Kuk, Mugumamp and Warrawau, this vegetation history represents the establishment of an agricultural landscape in the Upper Wahgi Valley by the mid-Holocene.
Archaeobotanical evidence of plants

Archaeobotanical investigations at Kuk employed macrofossil (e.g. seed, wood) and microfossil (e.g. phytolith, pollen, starch grain) techniques. The archaeological work documents a wide range of traditional food plants in the Kuk vicinity at various times in the past (Table 2, at http://antiquity.ac.uk/ProjGall/denham). Residue analysis of the used edges of stone tools from early and mid-Holocene contexts indicates that Colocasia taro, cf. Zingiber gingers, and other starchy and woody plants were being exploited (Denham et al. 2003: 191).

The most significant early Holocene additions to the suite of edible plants present in the Kuk vicinity are Colocasia taro and Eumusa bananas (Denham et al. 2003: 191-2; cf. Wilson 1985: Table 3, at http://antiquity.ac.uk/ProjGall/denham). Colocasia taro has been identified from starch residues on the cutting edge of a flake collected from the fill of an early Holocene feature, as well as on artefacts collected from within grey clay and the fill of a Phase 2 feature (Denham et al. 2003: 191). Eumusa section banana phytoliths are present at the base of grey clay sealing a 10 000 year-old palaeochannel (see Figure 5). Intact Musa phytolith chains within grey clay contexts are significant because they signify a local origin. Articulated chains of Musa phytoliths are fragile and are suggestive of local in situ decomposition and reflect limited post-depositional disturbance and translocation. Peaks within early Phase 2 contexts are, given their archaeological associations, more important and show banana phytoliths, including those of Eumusa section, accounting for up to 9 per cent of all phytoliths. Given the low productivity of phytoliths in bananas relative to grasses, elevated frequencies in Phase 2 contexts have been interpreted to represent the cultivation of bananas on the wetland margin within a landscape degraded to grassland (Denham et al. 2003: 191-2).

In New Guinea, Colocasia taro is presumed to be a lowland plant due to greater phenotypic variation among contemporary wild populations at lower altitude (Yen 1991: 77, 1995: 835). The present-day altitudinal range of Colocasia taro is assumed to be a product of agronomic selection (Yen 1995: 843). Similarly, wild Eumusa banana populations only occur at lower altitudes than Kuk in New Guinea (Argent 1976; Simmonds 1962), although like Colocasia taro, they may have spread to higher altitudes independently of human action as post-LGM climates ameliorated.

Although the mechanisms for the diffusion of Colocasia taro and Eumusa section bananas to the Highlands are unclear, these plants were potentially important sources of starch for inhabitants in the early Holocene. Earlier occurrences of these and other plants may yet be found given the absence of artefacts and the lack of detailed multi-disciplinary investigations of stratigraphy dating to the Late Pleistocene at Kuk and other Highland sites. The lack of correlation between archaeobotanical remains and archaeological phases at Kuk indicates that plant exploitation was not restricted to the wetland margin during the early and mid-Holocene. Most edible plants in the Highlands are traditionally cultivated asexually from wild populations in the vicinity and, therefore, many are anticipated to be continually represented in the archaeobotanical record.

Colocasia taro and Eumusa bananas, along with breadfruit (Artocarpus altilis), sago (Metroxylon sagu), sugarcanes (Saccharum spp.) and some yam species (Dioscorea spp.), are thought on phytogeographic and genetic grounds to be indigenous to, and domesticated in, the New Guinea region (De Langhe & de Maret 1999; Lebot 1999; Matthews 1991, 1995, 2003b). Indeed, Lebot states (1999: 626): "New Guinea and some parts of Melanesia have
been areas of domestication and still are important centres of diversity for species that also exist in Asia". The archaeobotanical findings from Kuk and other sites for Colocasia taro (Haberle 1995; Loy et al. 1992) provide strong corroborating evidence for these interpretations and suggest that the New Guinea region was a major centre of plant domestication.

Reconsidering the emergence of agriculture in New Guinea

Timing: early or mid-Holocene?

Early evidence of occupation at several sites in the Highlands dates to the terminal Pleistocene and early Holocene (Golson 1991b: 88-9). Although, in part, this trend may be apparent and reflect a "temporal-decay effect", i.e. comparatively fewer open sites survive with increasing age, it may also reflect greater populations of mobile groups living in the Highlands. Based on the inventory at Kuk, a broad range of edible plants was present in the Highlands during the Late Pleistocene (see pre-P1 in Table 2), which together with hunting and foraging for insects and grubs could have facilitated permanent occupation of higher and lower altitude regions of the interior following initial colonisation of the island (cf. Groube 1989). Throughout this period, mobile groups may have ranged across the interior via the expansive glacial grasslands that connected inter-montane valleys (Hope & Hope 1976) and utilised lowland resources, such as sago (Metroxylon sagu), as well as those in the Highlands.

At the end of the LGM and prior to stabilisation in the early Holocene, Highland climates are considered to have fluctuated considerably and to have been subject to greater interannual variability than is experienced in the current El Niño-related climate regime (Haberle et al. 2001). As suggested for other parts of the world (Bellwood 1996), fluctuating climates after the LGM may have stressed existing plant management practices in Highland New Guinea and necessitated more interventionist (i.e. greater ground preparation, tending and weeding of plants) and more extensive (i.e. greater disturbance of forest canopy to increase habitat diversity) plant exploitation strategies in order to maintain yields and a broad-spectrum diet (Haberle 1993: 305-8). Such strategies may be represented by the asynchronous and non-cumulative records of human-induced forest disturbance using fire in the Highlands in the Late Pleistocene (e.g. Haberle 1998; Hope 1983; Powell 1984). Additional "forcing" occurred during the early and mid-Holocene as people sought to obtain food in increasingly degraded and resource-poor environments on the floors of the larger inter-montane valleys. The signatures of more extensive and interventionist strategies are apparent during the early and mid-Holocene at Kuk, as well as at other archaeological and palaeoecological sites at wetlands in the Highlands.

During the early Holocene (10 200-9900 cal BP) at Kuk, and perhaps elsewhere in the Upper Wahgi Valley, people used fire to increasingly disturb and modify the mixed montane forest and soils on the valley walls. The resultant landscape comprised a continually changing mosaic of primary and secondary forest, regrowth and grasslands on the dryland slopes and variously disturbed riparian and wetland environments. Several high-caloric and nutritious plants were present in the Kuk vicinity including Castanopsis spp., Colocasia taro, Musa bananas (including identifiable members of Eumusa section with the onset of grey clay deposition), Pandanus spp., cf. Setaria palmifolia, and cf. Zingiberaceae. These plants, supplemented by hunting and foraging, could have been sufficient to sustain broad-spectrum diets for permanent
occupants of the Highlands. At this time, people were adventitiously exploiting slightly raised and drier ground adjacent to a palaeochannel at Kuk, where there is evidence suggesting digging and staking within a plot and the exploitation of *Colocasia* taro and other starchy and woody plants.

By the mid-Holocene (6950-6440 cal BP), the forests on the floor of the Upper Wahgi Valley had been altered to grassland or to secondary regrowth. Within relatively nutrient poor grassland environments, people gradually increased their degree of intervention in the management of significant food plants, especially high-energy staples. Most plants could still be collected or transplanted from primary and secondary forest and regrowth habitats in the valley. At this time, mounds were made within cleared plots along the wetland edge and planted with bananas and other inter-cropped plants. *Colocasia* taro, cf. *Zingiber* gingers and other starchy and woody plants were processed, presumably for consumption.

Multi-disciplinary lines of evidence provide an impression of plant exploitation on the wetland margin in the early Holocene. Similar palaeoecological signals, but without accompanying archaeological remains along the wetland edge, persist for the next 3-4000 years during grey clay deposition. Although suggestive of swidden-type cultivation (Denham 2004), the evidence is currently insufficient to determine whether these early Holocene practices are comparable to contemporary agricultural practices in the region (cf. Bourke 2001; Brookfield & Hart 1971: 94-124; Powell & Harrison 1982; Powell et al. 1975). By the mid-Holocene, a clearer picture of agricultural practices emerges and their effects are clearly documented in the cultivation and use of plants (e.g., bananas and *Colocasia* taro, respectively), some of which are considered to have undergone domestication in New Guinea, and in the dramatic transformation of the environment with the degradation of forest to grassland. Archaeological remains of prehistoric mound preparation on the wetland edge provide the foundation for interpretations of the archaeobotanical and palaeoecological evidence. Taken together, the multi-disciplinary lines of mid-Holocene evidence are comparable to contemporary agricultural practices and their effects in the Highlands of New Guinea.

**Location: Highlands or lowlands?**

Lowland environments and inhabitants were not subject to as severe climate-induced stresses as the Highlands during the terminal Pleistocene and the Holocene. Lowland inhabitants had continuous access to a broad range of fauna and nutritious and high-caloric food plants. Of most significance are a range of indigenous nut-bearing (e.g., *Artocarpus altilis*, *Barringtonia* spp., *Canarium* spp., *Cocos nucifera*, some *Pandanus* spp., *Terminalia* spp.) and starch-bearing trees (e.g., *Metroxylon sagu*), which have restricted lowland distributions (Bourke 1996; Yen 1995: 833-40). Additionally, a broad range of terrestrial, riverine, lagoonal and littoral fauna, including numerous freshwater fish, reptiles and shellfish, have distributions restricted to the lowlands. The relative abundance of edible tree resources led to an early focus on arboriculture in the lowlands, possibly from the terminal Pleistocene (Yen 1996: 41). A focus on managed stands of trees supplemented by hunting, fishing, foraging and garden horticulture created diverse practices some of which are not readily classified as agricultural or hunter-gatherer (Dwyer & Minnegal 1991; Roscoe 2002), but are “ambiguous” in terms of such traditional terminology (Terrell 2002; Terrell et al. 2003).
New evidence and revised interpretations of early agriculture in Highland New Guinea

The diversity of present and, by extension, past practices blurs any clear distinction between types of Highland and lowland subsistence. In the Highlands, however, there is a greater reliance on garden horticulture based on the vegetative propagation of vegetables and root-crops. Garden horticulture is practiced more intensively and forms the subsistence base in the Highlands, whereas in many lowland locales it supplements arboriculture and other activities.

Multiple lines of archaeological, archaeobotanical and palaeoecological evidence suggest that agriculture in New Guinea, manifest as extensive (swidden) or intensive (semi-permanent and short fallow wetland and raised bed) cultivation, originated in the Highlands. Currently, however, there is a lack of comparable evidence for lowland subsistence, particularly arboriculture, to test this proposition (for exceptions see Swadling et al. 1991; Yen 1996). There is little archaeological and palaeoecological evidence to indicate the expansion of agriculturalists from the lowlands brought plants and horticultural practices into the Highlands during the terminal Pleistocene or early Holocene. Although the altitudinal range of *Colocasia* taro and some *Musa* bananas lies dominantly within the lowlands implying a lowland origin for these plants, the upper altitudinal limits lie within or close to the Highland valleys. The appearance of these starch-rich plants at Kuk at the beginning of the Holocene may relate to natural dispersal processes (i.e. seed-dispersed under warming climate conditions) as much as to human agency (i.e. brought by mobile groups engaged in an extensive form of plant exploitation based on vegetative propagation).

**Conclusion**

Recent multi-disciplinary investigations have filled out previous, largely speculative chronologies of prehistoric plant exploitation (Harris 1995) and confirm previous interpretations that agriculture arose independently in New Guinea (Table 3). New multi-disciplinary investigations at Kuk have advanced previous interpretations of prehistoric plant exploitation in the Highlands of New Guinea in two significant ways.

First, multi-disciplinary lines of evidence (including archaeological, archaeobotanical, palaeoecological and stratigraphic) show that agriculture was practiced in the Upper Wahgi Valley by at least 6950-6440 cal BP and probably much earlier. The evidence for earlier plant exploitation practices at Kuk is insufficient to be definitive of agriculture, as previously claimed (Golson 1977a: 613-5, 1991a; Golson & Hughes 1980; Hope & Golson 1995: 824). The timing of the emergence of agriculture in the Highlands of New Guinea requires clarification through greater interpretative resolution of the Phase 1 record at Kuk and the excavation of additional sites with evidence of early Holocene plant exploitation.

Second, agriculture may have emerged in the Highlands of New Guinea as opposed to the lowlands. Golson suggested that agriculture originated in the lowlands and spread with expanding populations into the Highlands as climates ameliorated at the beginning of the Holocene (Golson 1991b: 88-9; Hope & Golson 1995: 827-8). It is argued here that agriculture emerged from broad-spectrum plant exploitation practices in the Highlands which had enabled permanent occupation of the interior during the Late Pleistocene. Climatic (Late Pleistocene) and environmental (early to mid-Holocene) forcing of existing plant exploitation practices led to the development of more interventionist and extensive strategies in the Highlands. Although the specific mechanisms remain uncertain, an increasing focus
on major sources of starch, including *Colocasia* taro and *Eumusa* bananas, were central to the emergence of agriculture in the Highlands.

As with an earlier debate concerning arboriculture (compare Kirch 1989 to Swadling et al. 1991 and Yen 1996), agriculture in New Guinea was traditionally viewed as being of Southeast Asian origin (e.g. Sauer 1952). The archaeological, archaeobotanical and palaeoecological findings at Kuk corroborate phytogeographic and genetic interpretations of independent plant domestication in Melanesia and demonstrate that agriculture emerged in New Guinea independently of any South-east Asian influence by at least 6950-6440 cal BP. Indeed, the early Holocene *Eumusa* section bananas at Kuk solidify previous interpretations for the early diffusion of domesticated plants from New Guinea and their subsequent influence on the development of agriculture in Southeast Asia (De Langhe & de Maret 1999: 378-82) and Africa (Mbida et al. 2000, 2001). Such findings open up new possibilities for interaction between mainland Southeast Asia and New Guinea during the early and mid-Holocene (i.e. prior to Austronesian dispersal into Indo-Malaysia and Melanesia) and require us to rethink the origins and spread of agriculture in the Pacific, Southeast Asia and beyond.

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New evidence and revised interpretations of early agriculture in Highland New Guinea


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New evidence and revised interpretations of early agriculture in Highland New Guinea


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